Solar Occultation Satellite Science Team Meeting

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Solar Occultation Retrieval Algorithm Development

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Objectives

- **Quantitative evaluation/comparison of current POAM II/III & SAGE II/III retrieval algorithms.**
- **Develop optimal approach to the UV/Vis solar occultation retrieval problem by:**
  - **Synthesizing current approaches**
  - **Exploring new ones.**
- **Apply resulting algorithm to POAM and SAGE data.**

UV/Visible Solar Occultation

A common POAM/SAGE algorithm is possible because of the fundamental similarity of the instruments:

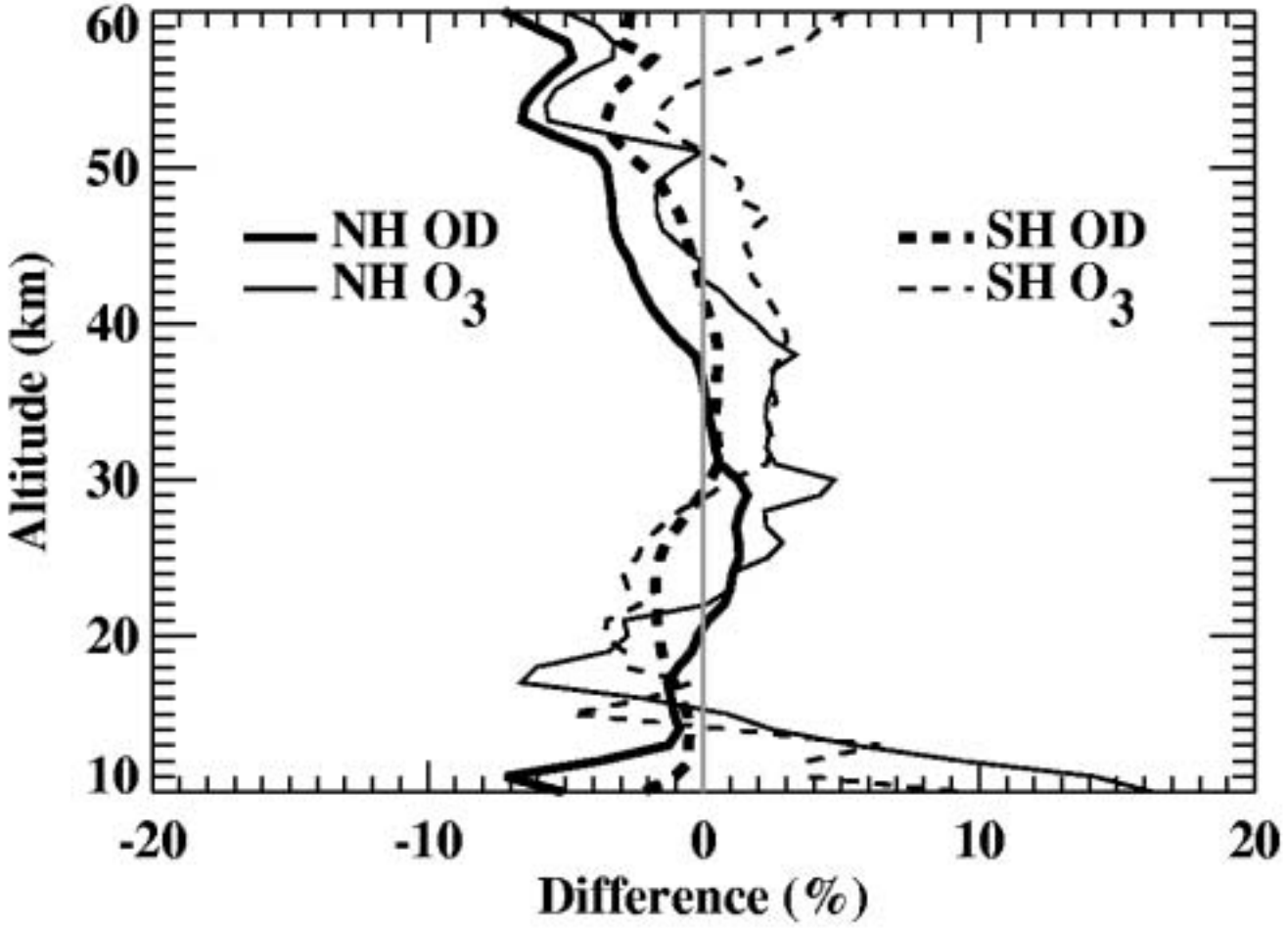
- **Same basic measurement/viewing geometry.**
- **Common spectral range.**
- **Similar spatial field of view.**

⇒ **The fundamental forward model & retrieval problem is identical for these four instruments.**

Only significant difference is spectral sampling.

POAM II/III – 9 channels **SAGE II – 7 channels** **SAGE III – 86 channels**

Motivation - O_3 Retrievals



Comparison of POAM III-SAGE II retrieved O_3 & 600-nm OD.

Forward Model

Fundamental measurement is slant optical depth:

$$\delta^i_{meas}(z_\perp) = \sum_\alpha \delta^i_\alpha(z_\perp) \qquad (i = 1, N_\lambda)$$

$$\delta^i_\alpha(z_\perp) \equiv -\ln \int_{\Delta\nu_i} d\nu\, Q_i(\nu)\, I_o(\nu)\; e^{-\int_{z_\perp} ds\, k_a(\nu, z(s), T(s), P(s))}$$

$$\delta^i_{meas}(z_\perp) = \delta^i_{aer}(z_\perp) + \sum_\alpha \sigma^i_\alpha(T, P, N_\alpha)\, N_\alpha(z_\perp)$$

$$N_\alpha(z_\perp) = \int_{z_\perp} ds\, n_\alpha(s)$$

(α=RS, aer, O_3, NO_2, H_2O, O_2)

Retrieval Problem

We need to invert $y = F(x)$

where

$$y = \left[\delta^{1}_{meas}(z_{\perp}), \ldots, \delta^{N_{\lambda}}_{meas}(z_{\perp}) \right]$$

$$x = \left[n_{O_3}(z), n_{NO_2}(z), n_{H_2O}(z), n_{mol}(z), k_{aer}(\lambda, z) \right]$$

<u>Various approaches are possible</u>:

- **1-step or 2-step (spectral/spatial inversion).**
- **Simultaneous or sequential species separation.**
- **Many numerical inversion techniques exist.**
- **Handling of Rayleigh and aerosol scattering terms.**

POAM/SAGE Algorithm Summary

Instrument	Overall Approach	Spectral Inversion	Spatial Inversion	Rayleigh Scattering	Aerosol Spectral Dependence
POAM II	Two Step 1. Spectral 2. Spatial	Simultaneous solution. Nonlinear Opt. Est.	Linear Opt. Est.	Fixed to UKMO	Global nonlinear fit
POAM III	〃	〃	〃	Retrieved from UV channels (> 30 km)	〃
SAGE II	〃	Sequential, Iterative for O_3, NO_2, Aer H_2O off-line	Modified Chahine	Fixed to NCEP	Mie scattering kernels
SAGE III	〃	Simultaneous O_3/NO_2 Residual Aer H_2O off-line	〃	Fixed to NCEP (A band ?)	Taken directly from residual optical depth

Proposed Work

- **Develop generalized forward model.**
- **Implement generalized retrieval algorithm (heritage from POAM* and StOLSS).**
- **Evaluate algorithm using multiple methods:**
  - **Simulations (range of atmospheric conditions).**
  - **Coincident POAM/SAGE measurements.**
  - **Comparison with correlative measurements.**

*** Lumpe, *et al*., *J. Geophys. Res*., *107*(D21), 4575, 2002.**

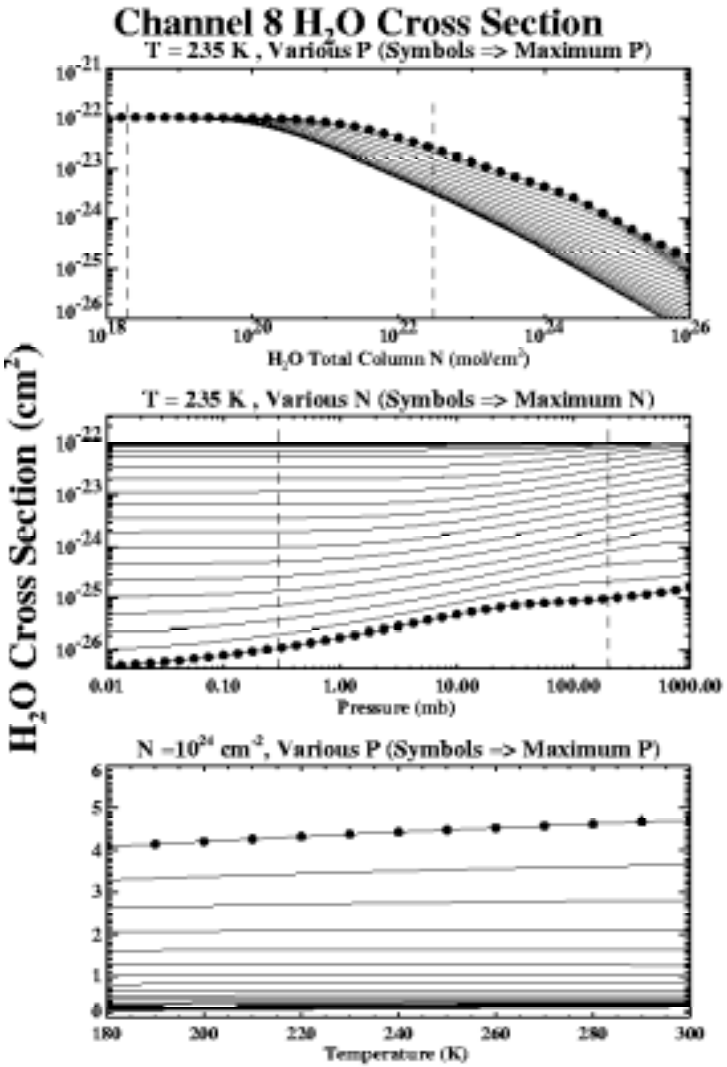
Forward Model Capability

- **Atmospheric transmission from the ground to 90 km.**
- **Full treatment of atmospheric refraction.**
- **Arbitrary spectral sampling.**
- **Efficient path integration routines, incorporating horizontal gradients (non-spherical symmetry).**
- **Up to date spectroscopy.**
- **Full line-by-line calculation for O_2/H_2O.**
- **Look up tables of effective cross sections: $\sigma_{\alpha}^{\lambda_i}(T, P, N_{\alpha})$**
- **Variety of aerosol and cloud models.**

H_2O Spectroscopy

POAM III Channel 8 H_2O Cross Section

$$\sigma^{8}_{H_2O}\left(T, P, N_{H_2O}\right)$$



Generalized Retrieval Algorithm

Current capabilities:

- **Arbitrary spectral sampling/vertical resolution.**
- **Simultaneous retrieval of multiple (variable) species using Optimal Estimation.**
- **1-step or 2-step inversion.**
- **Detailed retrieval diagnostics (avg kernels, errors).**

New approach will allow:

- **Simultaneous or sequential species retrievals.**
- **Alternative numerical approaches inversions.**
- **Alternative aerosol parameterizations.**

Retrieval Characterization

We can characterize many aspects of the retrieval algorithm using the retrieval averaging kernels:

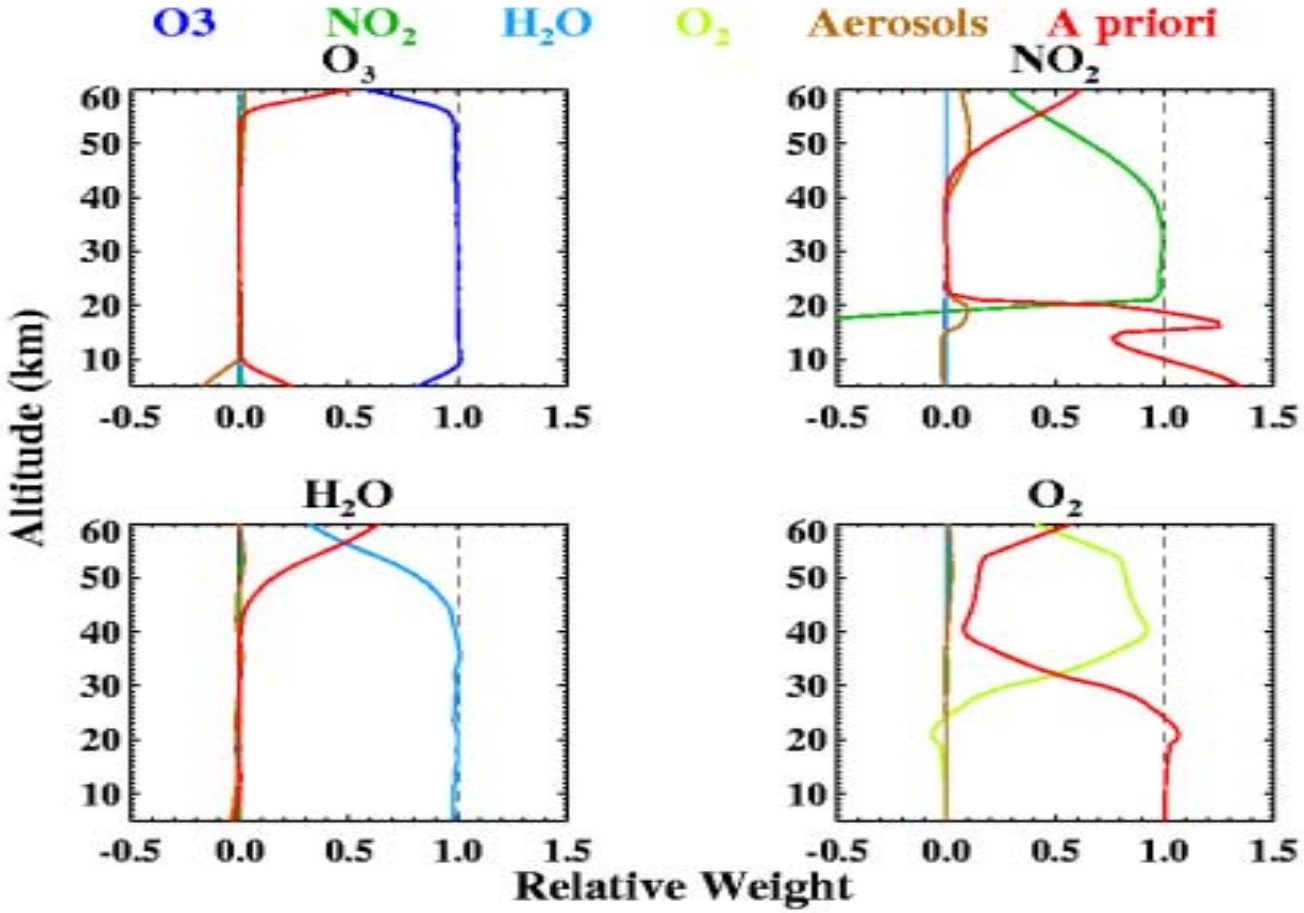
$$A^{\alpha,z_i}_{\beta,z_j} \equiv \frac{\partial\,\hat{x}(\alpha,z_i)}{\partial\,x(\beta,z_j)}$$

(α, β = RS, aer, O_3, NO_2, H_2O, O_2)

- **Vertical resolution from diagonal elements** $(\alpha = \beta)$
- **Species correlation from off-diagonal elements** $(\alpha \neq \beta)$
- **Spectral resolution of aerosol retrievals** $\left(\alpha = k^{\alpha}_{aer}\,;\beta = k^{\beta}_{aer}\right)$
- **Information content (*a priori* bias)**

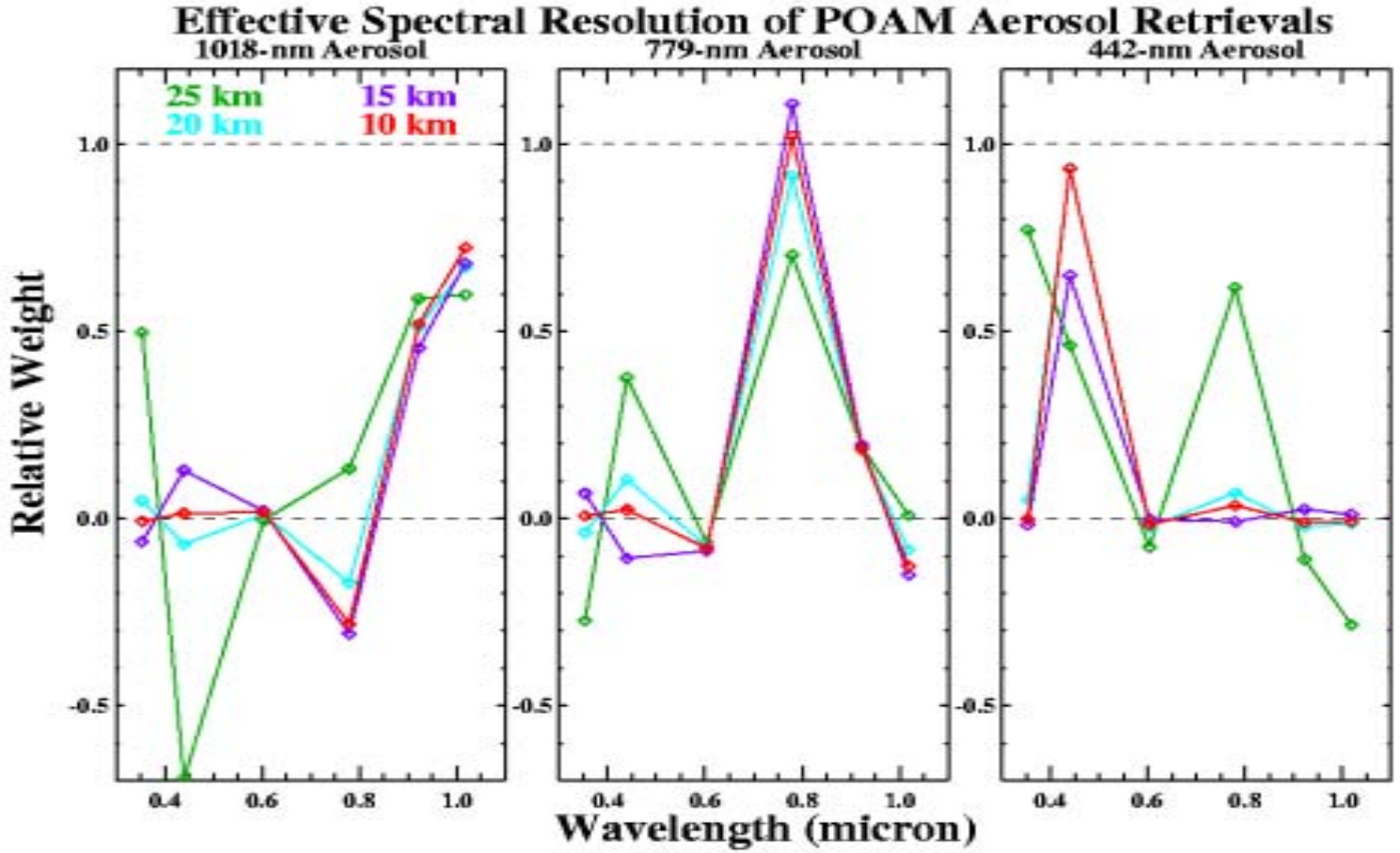
POAM Species Correlations

A priori dependence and species correlation in gas retrievals.



POAM Aerosol Spectral Resolution

$$\ln \delta_{aer}(\lambda) = \mu_o + \mu_1 \ln \lambda + \mu_2 \ln^2 \lambda$$



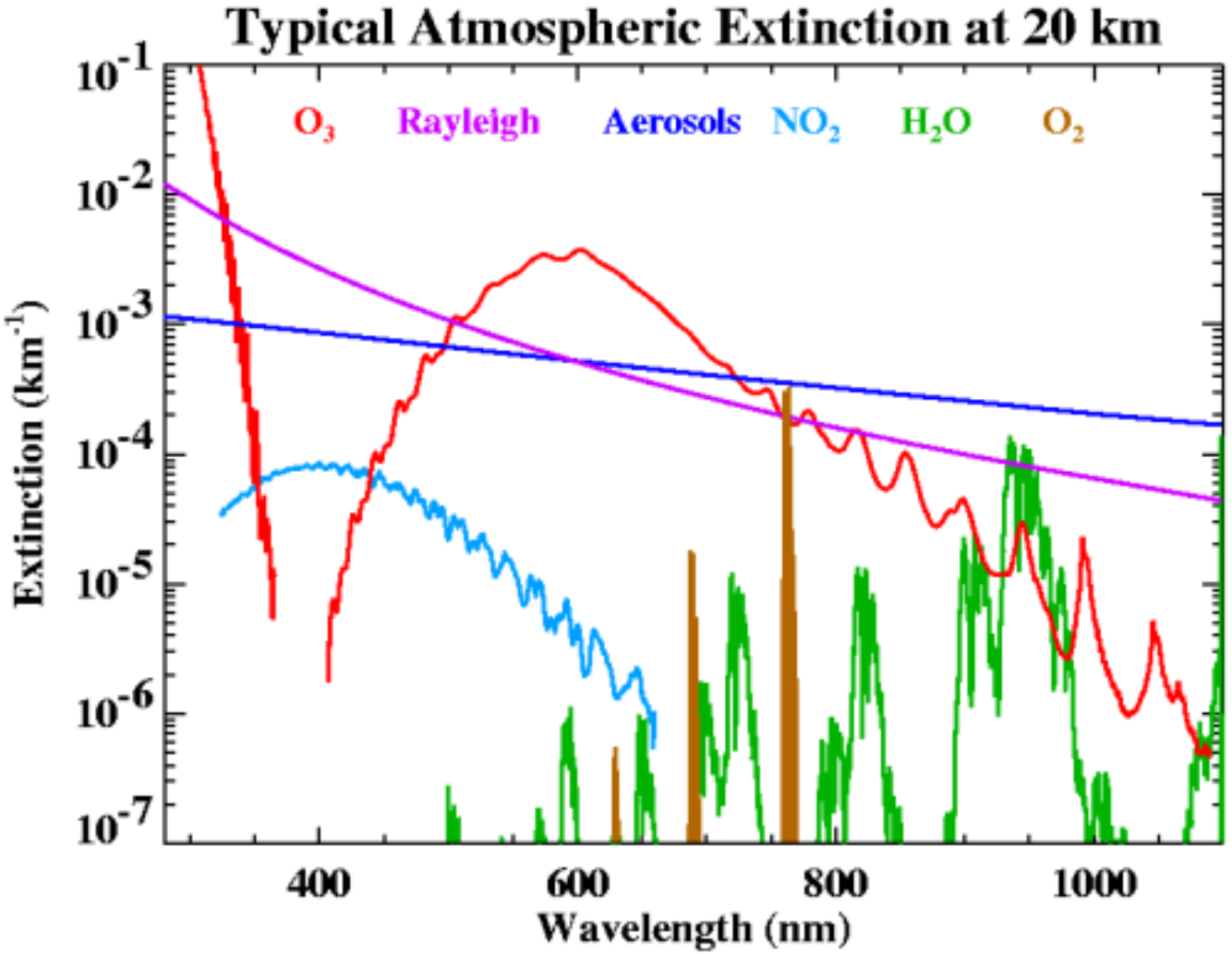
Some Issues to Address

- UT/LS O_3 (aerosol separation issues).
- Aerosol parameterization and spectral dependence.
- Coupling of blue channel aerosols and NO_2.
- SAGE II H_2O (aerosol/O_3 interference, spectroscopy).
- SAGE III retrieval issues (species coupling, etc).
- O_2 A band retrievals (compare SAGE III & POAM III).
- Cross section and spectroscopy issues.
- Full retrieval characterization and error analysis.

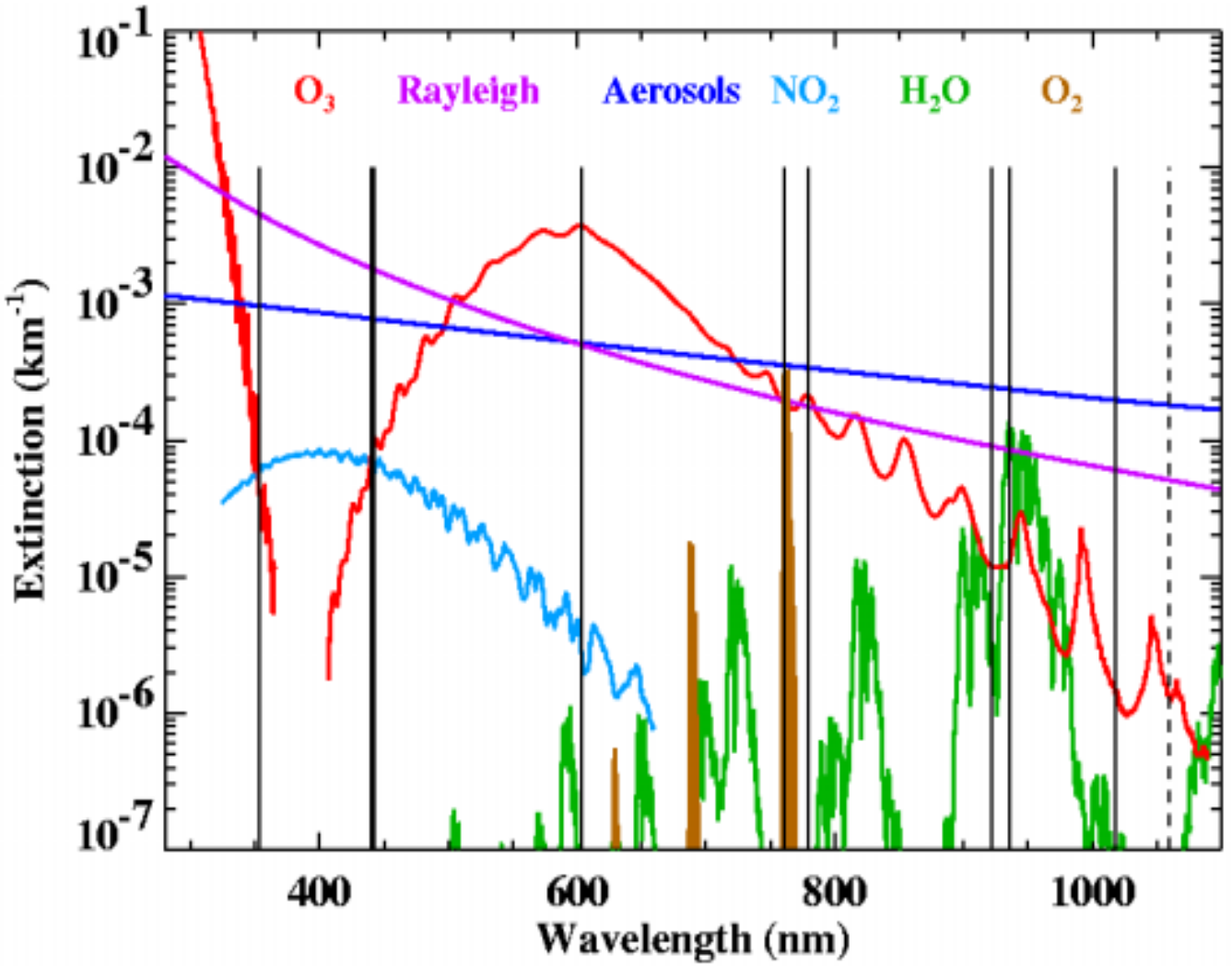
Summary

- **We propose to develop general forward model and retrieval algorithms for UV/Vis solar occultation instruments.**
- **These algorithms will allow us to study a number of important retrieval issues which impact the current agreement between POAM and SAGE data sets.**
- **Use of a common algorithm implementing an optimal retrieval approach could improve the consistency of these data sets in the future.**

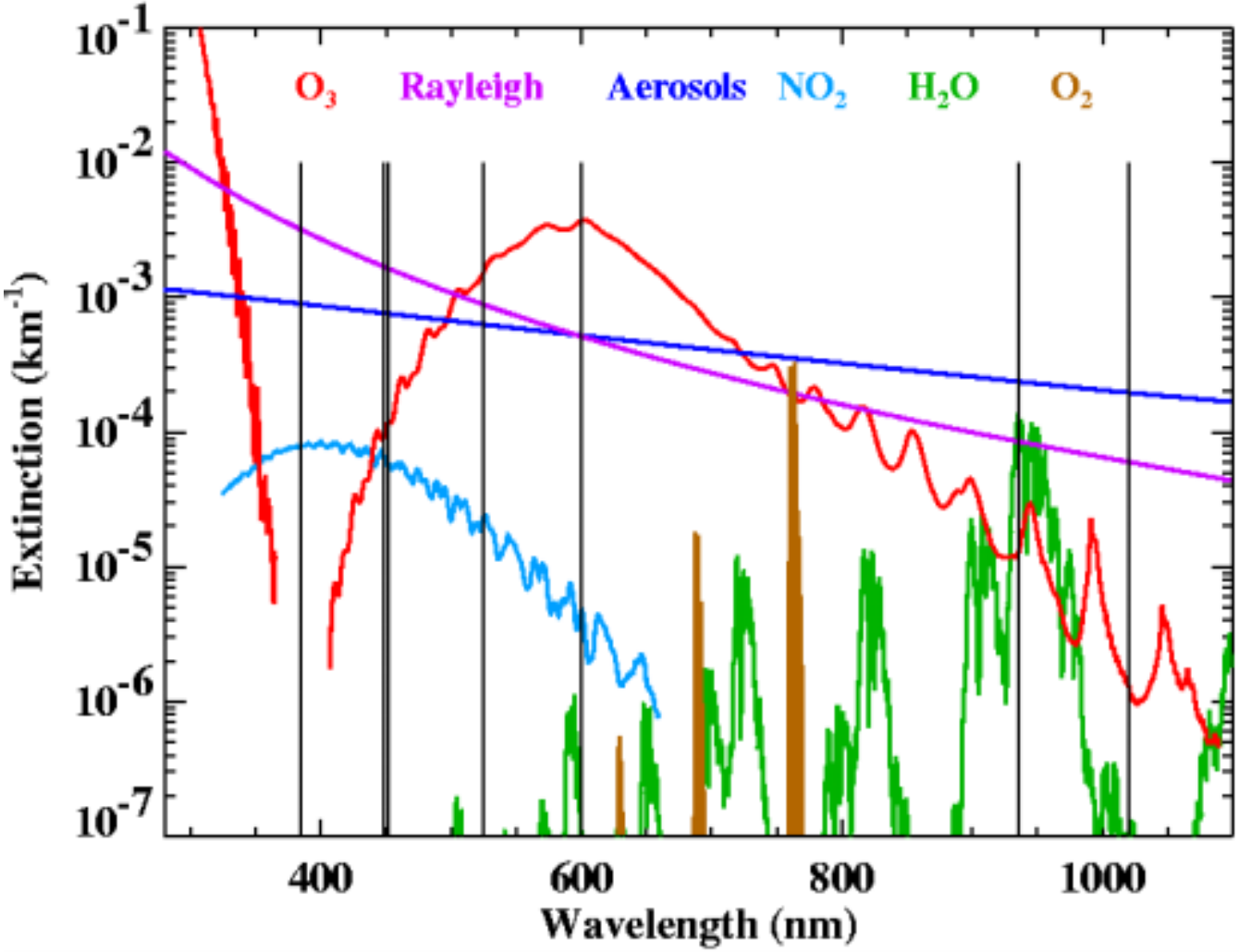
Primary Scattering & Absorption Features for POAM/SAGE



POAM Spectral Sampling (9 channels)



SAGE II Spectral Sampling (7 channels)



SAGE III Spectral Sampling (87 channels)